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Row Spacing and Irrigation Interval Effects on Yield and Yield Components of Soybean [*Glycine max* (L.) Merr.]

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Abstract: Short-season production systems in soybean [*Glycine max* (L.) Merr], such as double-cropping or late-sowing require high populations or narrow row spacing for high yield. The soil water- row spacing interaction suggests the need for a better understanding of how row spacing affects water utilization and the subsequent effects on yield. Changes in soil water storage have been used to characterize long-term trends (5 to 10 days) in water depletion. The objective of this study was to determine the effects of row spacing and irrigation intervals on yield, plant height, first pod height, number of branches, number of nodes, number of pods and seed yield per plant for 2 year period. The study had four row spacing (50-30, 70-30, 80-40 and 70-70 cm), four irrigation intervals (3, 6, 9 and 12 day intervals) and three replication in Harran Plain conditions in Turkey. Decreasing row spacing reduced the seed yield per plant but led to an increase in yield per hectar. Yields were the highest at 50-30 cm (3752.6 kg ha^{-1}) row spacing and 3-6 day irrigation intervals (3607 and 3744.1 kg ha^{-1}, respectively) and were the lowest at the 70-70 cm row spacing (3096.6 kg ha^{-1}) and 12 day intervals (2752.4 kg ha^{-1}). For short-season production systems in soybean, narrow row spacing ensured early canopy coverage and maximized light interception, crop growth rate and crop biomass, resulting in the increased pod number and yield potential per unit area.

Key words: Row spacing, irrigation interval, soybean

INTRODUCTION

Soybeans are perhaps the most light sensitive of the major farm crops produced in present day agriculture. The crop is particularly responsive to quality of sunlight since it affects plant height, branching, leaf area, time of flowering, lodging and maturity. The leaves near the top of a fully developed soybean canopy intercept over 90% of the incoming radiation; less than 2% of the incoming radiation reaches the soil surface. These soybean canopy characteristics greatly reduce soil moisture losses through evaporation and thereby permits a larger percentage of the soil moisture to be utilized through the plant in photosynthetic and metabolic processes[1].

Efforts have been made to increase the yield per unit area by raising the number of plants per unit area. The seed yield (SY) of soybean can be calculated by using the following equation:

[SY=number of plants m^{-2} x number of seeds per pod x number of pod x weight of 1000 seeds (g)][2].

Narrow row spacing (RS) have a significant effect on yield. When the seeding rate was low enough to prevent lodging yield advantages of 10 to 20% were obtained from planting soybeans in 17 cm rows as compared with wider spacings[3]. Data reported by Safo-Kantanka and Lawson[4], Cooper[5], Weber *et al.*[6], Reiss and Shorewood[7]. Donovan *et al.*[8] suggested that narrow RS have a significant effect on yield. Boydak and Isler[5] found that higher first pod height (FPH) and yield from 40 cm RS but higher number of pods (PN), number of nodes (NN), number of branches (BN) and SY $plant^{-1}$ from 60 cm RS than 30 and 50 cm RS. Öktem and Toros[9] reported the highest yield from 50 cm RS among 50, 60, 60-30, 70, 70-30, 80 and 80-30 cm in a double crop production system. Emirolu *et al.*[10] reported that the highest plant height (PH) and FPH were obtained from 20 cm RS but the highest yield and number of branches from 40 cm RS among 20, 40 and 60-20 cm RS in soybean. Board *et al.*[11] have planted soybean in its normal planting date and late planting date using 50 and 100 cm RS. As a result, the highest yield were obtained from the 50 cm RS for both planting dates. Taylor *et al.*[12] found that irrigation is increasing the crop growth rate, NN, PH, total biomass and leaf area.

Many factors, such as the length of growing season, climate (temperature, rainfall, humidity, evaporation and

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wind speed), the humidity of soil topography and soil structure determine the water requirement of the plants.

The amount of water uptake through evaporation from the soil and transpiration from the plant is under strong influence of environmental conditions. The transpiration from the plant tissues depends on canopy size, wind and water potential and other leaf characteristics that offer for resistance around the plant root. Thus, if the plants are planted wide apart, the soil surface per unit area is high and in contrast, if the plants are planted density, the leaf area index per unit area is higher normally.

The soil water- row spacing interaction suggests the need for a better understanding of how RS affects water utillization and the subsequent effects on yield. Changes in soil water storage have been used to characterize long-term trends (5 to 10 days) in water depletion[13].

The specific objective of this study was to determine the effect of RS and irrigation intervals (IRI) on soybean yield and yield components.

MATERIALS AND METHODS

In this study, A-3935 soybean cultivar was grown in June of 1998 and 1999 in the Faculty of Agriculture, Department of Field Crops at Harran University of Turkey. The experimental design for four IRI (3, 6, 9 and 12 days) and RS (50-30, 70-30, 80-40 and 70-70 cm) trials was a split-plots with three replications. The research field is located in an arid climate in which the summer is hot and dry and the winter is warm and dry. The altitude of the research field is approximately 464-467 m. Above the sea level the field is located at 37^{0}08' N and 38^{0}46' E.

According to the results of some physical and chemical analyses in the experimental soil, trials were conducted on a silted-clay soil[13] at pH 7.5[14] and lime content of 99000 ppm[15] without salinity problem (620 ppm)[16] which was deficient in organic matter (11200 ppm)[17]. Modified potassium was 78 kg da^{-1} [18].

Field capacity between (32.71-33.19%), permanent wilting point (21.18-22.55) and bulk density of experiment soils were changed. Irrigation water was determinated in C_2S_1 classification. Soil moisture changing in 0-30 cm layers was designated by gravimetric method. Irrigation was applied as sprinkle in the afternoon because of wind speed. 12 sprinkles were laid down in 6x6 m interval as square per irrigation plot.

The meteorological data were recorded from planting date to the harvest of each treatment in Table 1.

All treatments were fertilized with 100 kg ha^{-1} nitrogen (50% after planting) and 60 kg ha^{-1} phosphorus in each year. Seeds were hand planted in rows as dense as possible in non-irrigated seedbeds and later arrangement was made for seeds planted using a RS of 3 cm in 4 m rows. Germination percentage was a perfect 100%. The plots were sprinkle irrigated after planting to provide uniform emergence. The four RS were alternating rows of 50-30, 70-30, 80-40 cm in 6 rows-plots and 70-70 cm in 4 rows-plots.

Table 1: Monthly mean temperatures during the growing season for soybean (June-October) in 1998 and 1999 in Şanlıurfa of Turkey

	Mean temp. (°C)		Min. temp. (°C)		Max. temp. (°C)		Total rainfall (mm)	
Month	1998	1999	1998	1999	1998	1999	1998	1999
June	29.4	28.8	17.8	18.8	41.2	40.0	0.6	1.6
July	33.0	32.5	19.8	21.5	45.4	43.2	Nr[a]	NR
Aug.	33.4	31.2	22.6	20.5	43.0	43.0	NR	26.0
Sept.	27.0	26.2	15.1	17.0	39.6	36.6	0.0	NR
Oct.	21.5	21.0	10.2	11.3	34.1	35.6	0.1	8.4

[a] NR, no rainfall

50-30-50-30-50-30 cm	= 83.125 seeds m^{-2} or 831.250 seeds ha^{-1}
70-30-70-30-70-30 cm	= 66.5 seeds m^{-2} or 665.000 seeds ha^{-1}
80-40-80-40-80-40 cm	= 55.416 seeds m^{-2} or 554.160 seeds ha^{-1}
70-70-70-70 cm	= 47.5 seeds m^{-2} or 475.000 seeds ha^{-1}

Irrigation was continued until 15 to 20 days before harvest. Twenty plants per plot were randomly sampled at harvest to determine yield and yield component. For NN, pods and branches datas were obtained counting on the 20 plants. pH was measured from soil surface to top of the plants. Plants were harvested to measure SY from middle two rows of six rows per plot treatment. Harvest was done by hand.

The amount of irrigation applied to treatments was determined as the Cumulative Pan Evaporation (CPE) multiplied by Pan Coefficient (kp). Therefore, water equal to 100% of CPE was applied in the 3 day IRI, 80% of CPE the 6 day IRI, 60% of CPE in the 9 day IRI and 40% of CPE in the 12 day IRI.

Changes in soil water content at 0-30, 30-60 and 60-90 cm soil depths in each treatment plot was continuously determined by gravimetric method[19]. Determination of soil water content started before the first irrigation and continued until last irrigation before the harvest. First irrigation was applied to all treatments using sprinkler irrigation system during the experiments in 1998 and 1999 to bring the soil water content in 0-90 cm soil depth to field capacity.

The amount of required irrigation water was calculated by Class A Pan evaporation everyday[20]. Total evaporation was measured with a manual limnimeter with 0.1 mm accuracy. These measurements were checked with the readings from water flow meters mounted in each plot.

Crop water consumption equation for the treatments takes the form[19].

$$ET= P+I-R-D_p \pm \Delta S$$

Where ET is crop water consumption (mm); P is rainfall (mm); I is irrigation water (mm); R is surface runoff (mm); Dp is deep percolation (mm); ÄS is soil water content variation in crop root depth (mm). The area of experimental plot for each row space was:

For 50–30 cm row space: 2.5x4 m
For 70–30 cm row space: 3.0x4 m
For 80–40 cm row space: 3.6x4 m
For 70–70 cm row space: 2.8x4 m

The total plowing area for each plot was calculated as 47.2 m^2.

Statistical analysis was carried out using the software TARIST version 1 with general linear mode (GLM)[21]. Significant differences were determined using L.S.D (Least Significant Difference) multiple range test at $p<0.05$.

RESULTS AND DISCUSSION

Water use: Total applied water was 1,295, 1,055, 794 and 575 mm and evapotranspration rate of the soybean was 1,378, 1,191, 901 and 698 mm for 3, 6, 9 and 12 day interval, respectively, in 1998 growing period. Total applied water was 1369, 1,119, 836 and 601 mm and evapotranspiration rate of the soybean was 1,425, 1,264, 977 and 763 mm for 3, 6, 9 and 12 day interval, respectively, in 1999 growing period. There was a similar trend for applied water and water use of soybean in both years. These results are in agreement with the findings of Sepaskhah and Andam[22]. Since precipitation was higher in 1998 compared to 1999, soil moisture storage was higher in 1998 according to soil moisture in 1999.

Yield components: In mean of 1998 and 1999, PH, FPH, BN, NN, PN and SY were significantly affected by IRI and RS (Table 2).

Results showed that frequent IRI had better results than did the wide apart IRI. While the highest PH (86.96 cm) was obtained in 70-30 cm RS from 6 day intervals, the highest FPH (17.50 cm) in 80-40 cm RS, BN (1.82 $plan^{-1}$), NN (21.12 $plant^{-1}$), PN (70.05 $plant^{-1}$) and SY (24.12 g) in 70-70 cm RS were obtained from 3 day intervals. The lowest PH (59.86 cm) was obtained in 80-40 cm RS, the lowest FPH (14.18 cm) in 50-30 cm RS, BN (0.44 $plant^{-1}$), NN (15.07 $plant^{-1}$), PN (29.54 $plant^{-1}$) in 70-70 cm RS and SY (10.25 g) in 70-70 cm RS were obtained from 12 day intervals (Table 2).

According to the results, the plants planted in broader rows had higher BN, nodes pods and SY per plant than did the ones planted in narrow rows, but in PH and FPH in wide rows. The reason for this is probably that the plants in broader rows had larger growth area and eventually better benefited from a unit area. Similar results were recorded for the number of capsules as well. Since the capsules develop on the branches, the plants having higher BN had a higher number of capsules too.

The factors causing an increase in the BN were found to be effective on the number of capsules. This is because the plants in broader rows were less competitive for plant nutrients. The results are similar to those found by Boydak and Isler[2], Taylor *et al.*[12] and Emirolu *et al.*[10].

Yield: Table 3 show that in mean of 1998 and 1999, the IRI and RS had a significant effect on the yield per hectare.

Table 2: Averages results of yield components at RS according to IRI

	3 day interval	6 day interval	9 day interval	12 day interval
RS/years	Mean	Mean	Mean	Mean
PH (cm)				
50-30 cm	77.41a	81.67b	73.35a	66.81a
70-30 cm	77.87a	86.96a	74.35a	62.31b
80-40 cm	77.86a	79.80b	63.30b	59.86b
70-70 cm	77.52a	73.73c	64.93b	61.77b
L.S.D (5%)	3.25			
FPH (cm)				
50-30 cm	17.27a	17.18a	15.87a	14.18b
70-30 cm	14.40b	17.19a	15.65ab	16.29a
80-40 cm	17.50a	16.27a	14.58ab	14.37b
70-70 cm	15.85b	15.77a	14.29b	14.43b
L.S.D (5%)	1.39			
BN ($plant^{-1}$)				
50-30 cm	1.03ab	0.77b	0.63bc	0.75a
70-30 cm	1.17b	0.79b	0.52c	0.44b
80-40 cm	0.97c	1.32a	0.77b	0.80a
70-70 cm	1.82a	1.29a	1.04a	0.92a
L.S.D (5%)	0.19			
NN ($plant^{-1}$)				
50-30 cm	18.40b	16.82b	17.97a	16.80a
70-30 cm	19.54b	18.17a	18.20a	15.07b
80-40 cm	19.07b	18.77a	17.97a	16.29a
70-70 cm	21.12a	18.22a	17.53a	16.50a
L.S.D (5%)	1.20			
PN (plant)				
50-30 cm	40.10c	54.90a	40.10b	30.00b
70-30 cm	48.49b	45.98b	38.49b	29.54b
80-40 cm	51.35b	49.77b	40.90b	33.52ab
70-70 cm	70.05a	47.85b	49.53a	34.60a
L.S.D (5%)	4.51			
SY (g $plant^{-1}$)				
50-30 cm	15.63d	17.69b	14.74b	12.03b
70-30 cm	18.24c	20.10a	15.30b	10.42c
80-40 cm	20.81b	17.79b	17.41a	13.58a
70-70 cm	24.12a	20.93a	18.63a	10.25c
L.S.D (5%)	1.53			

Table 3: Averages results of yield at RS according to IRI

	3 day interval	6 day interval	9 day interval	12 day interval
RS/years	Mean	Mean	Mean	Mean
Yield (kg ha^{-1})				
50-30 cm	4346.3a	4278.2a	3624.8a	2761.1b
70-30 cm	3636.8b	4047.7a	3087.8c	2774.2b
80-40 cm	3167.6c	3092.1c	3402.0ab	3103.8a
70-70 cm	3277.2c	3557.6b	3180.7bc	2370.8c
L.S.D (5%)	250.8			

The highest yield per hectare was obtained in 50-30 cm RS from 3 and 6 day intervals (4346.3 and 4278.2 kg ha^{-1}, respectively). The lowest yield per hectare was obtained in 70-70 cm RS from 12 day intervals (2370.8 kg ha^{-1}). So generally increasing row distance decreased. (Table 3).

The yield per hectare generally decreased relatively with the increase in RS. This probably resulted from the fact that the increase in leaf unit index in a defined area caused an increase in the photosynthetic capacity of the plants in per area that would eventually lead to better uptake of plant nutrients. In addition, in RS, due to plant canopy the risk of water loss by evaporation could be less and the plants are less affected by atmospheric temperature. The increase in the number of plants in a narrow area provides a much better uptake from the soil. This naturally leads to an increase in the yield. Our results are in similarity with some research done by Boydak and Isler[2], Emirolu *et al.*[10]. Öktem and Toros[9], Board *et al.*[11], Taylor *et al.*[12], Reicosky[3], Safo-Kantanka and Lawson[4], Cooper[5].

This study showed that optimum yield could be obtained when sufficient crop nutrients and soil water content exist in the effective crop root depth. James *et al.*[23] state that there is a relationship between relative evapotranspiration and relative decrease in yield.

In this study, A-3935 soybean cultivar was grown in June of 1998 and 1999. The experimental design for IRI and RS trials was split-plots with three replications. The research field is located in an arid climate in which the summer is hot and dry and the winter is warm and dry.

The highest yield per hectare was obtained in 50-30 cm RS from 3 and 6 day intervals (4346.3 and 4278.2 kg ha^{-1}, respectively). The lowest yield per hectare was obtained in 70-70 cm RS from 12 day intervals (2370.8 kg ha^{-1}). So increasing row distance decreased yield except 12 day IRI (Table 3).

These results implies that obtaining the highest yield in soybean occurred when the crop was planted on rows as narrow as possible and irrigated with sufficient amount of water using 6 day intervals.

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